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On the Errors of a Photographed Réseau. By W. H. M. Christie, A. S. Eddington, and C. Davidson.

The investigation which is here described was undertaken in connection with the discussion of the results of the Greenwich photographs of Eros 1900–1901. The determination of the division errors of the réseau as imprinted on the photographic plates to the very high degree of accuracy required, is in some respects a new problem, so that some of the methods and results may be of interest.

An account of the preliminary determination of the errors of the réseau (No. 90), which was used for all the Eros photographs, is printed in the Introduction to the Astrographic Catalogue, Greenwich Section, vol. i. p. xxxvii. These provisional division errors were applied in the reduction of the measures of photographs, but a much more extensive investigation was felt to be necessary in order to deduce a trustworthy value of the solar parallax from the results.

A preliminary comparison made in 1903 between the réseau itself and photographs of it on seven plates had shown that there were sensible differences, which called for further discussion after the heavy work of measurement of the Eros plates had been completed. It may here be explained that the réseau is imprinted on the photographic plate by parallel rays from an electric lamp in the focus of the 13-inch object-glass of the Astrographic telescope, the réseau and the plate being mounted face to face, as nearly as possible in contact just outside the object-glass. It is to be noted that the parallel rays necessarily pass through the glass of the réseau from the back before falling on the silver film.

Under the ordinary conditions the réseau is reversed with the telescope in passing from east to west of the pier, the same edge of the plate being in contact with the bearing studs, on both sides of the pier. In consequence of this reversal the division errors of the central line 14 and the adjacent line 13 or 15, between which Eros is usually placed, affect the R.A. of Eros with opposite signs on photographs taken with the telescope east and west of the pier respectively, and thus directly enter into the value of the parallax deduced from morning and evening photographs, with telescope east and west respectively.

It was therefore necessary to determine the division errors of lines 13, 14, 15 with a degree of accuracy far beyond that required for the other lines.

What was required in this new investigation was the error of that part of the réseau where Eros falls, referred to the mean of that part of the réseau on which those stars fall, from which the co-ordinates of the plate centre were deduced. In the Greenwich results three series of places of Eros have been determined, viz. (1) Astrographic photographs using *reference stars* selected within 55′ of the centre; (2) Astrographic photographs using *comparison stars*

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selected within 25′ of the centre; (3) Thompson photographs using *comparison stars.* In series (2) the comparison stars may be considered to be, in the mean, fairly uniformly distributed over the square between the lines 9 and 19 in each co-ordinate; while in the other two series the stars were distributed over the square between lines 4 and 24. Different corrections must be applied to Eros in the two cases.

There were three steps in the determination:—

(1) A more accurate measurement of the errors of lines 13, 14, 15 on the silver réseau.
(2) Measurement of the systematic differences between prints of the réseau and the réseau itself.
(3) Examination of the straightness of the réseau lines.

As the declinations of Eros are not very important for parallax, only the errors in x have so far been investigated.

The numerical values of the errors given in this paper are for the scale of the Astrographic telescope ($1^{\mathrm{mm}} = 1'$). They must be halved before being applied to the Thompson photographs. The réseau was printed on both sets of photographs at the same time and in precisely the same manner, the object-glass of the Astrographic telescope being used to give a beam of parallel rays.

The micrometer used throughout was described in *M.N.*, vol. liii. p. 326, but has been somewhat modified since then. Two microscopes, whose distance apart can be adjusted, are connected by a bar which can move longitudinally in a slide. The réseau and scale (or photographic plate) to be compared are carried in a large frame, so as to be viewed one by each microscope. The frame can move in a slide perpendicularly to the line joining the microscopes. A fixed wire in the right-hand microscope is set on the required scale division (or other mark) by moving the bar which carries the two microscopes, by means of a slow-motion screw. A movable wire in the left-hand microscope is then set on the required réseau-line by turning a micrometer-head. In order that the same reading of the micrometer may always correspond to the same distance between the two points viewed, however the slides are moved, it is necessary that either the axes of the microscopes should be parallel, or that each slide should move accurately in its plane. Probably an appreciable error arises from the non-fulfilment of these conditions when the outer parts of the réseau are viewed; the error can be detected and eliminated by turning the réseau through 180° and re-measuring. It seems to be inappreciable within the area between lines 9 and 19.

(1) *Corrections to the adopted division errors of lines* 13, 14, 15 *on the silver réseau.*

In the original determination the division errors of lines 8, 14, and 20, referred to 2 and 26, were first determined (along $y = 14$) by comparing the intervals, 2–8, 8–14, 14–20, 20–26, with the

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same interval on a glass scale. The errors of the intermediate lines were then determined by the symmetrical method explained in the Introduction to the Astrographic Catalogue, vol. i. p. xxxvii.

In the re-determination, the object aimed at was to refer, with the greatest accuracy attainable, the central lines on which the place of Eros depends to the means of the lines used for reference or comparison stars, 4 to 24 or 9 to 19 respectively. With this object the interval between line 14 and each pair of lines from 4 to 24 was compared by means of the glass scale at $y=13{\cdot}5$ and $y=14{\cdot}5$, so that line 14 was referred in succession to the pairs of lines 4, 24; 5, 23; 6, 22 . . . . 13, 15, giving, after application of the provisional divisional errors, ten independent determinations of the division error of line 14 referred to a pair of lines. Similarly, line 13 was referred to each pair of lines 3, 23; 4, 24 . . . . 12, 14 and line 15 to each pair 5, 25; 6, 24 . . . . 14, 16. Since, in this method, each line is necessarily referred to pairs of lines symmetrically situated about itself, lines 13 and 15 could not be referred exactly to the same lines (4 to 24) as line 14, but it is clear that the accidental residual division error arising from the substitution of line 3 for line 24, and line 25 for line 4, in the two cases respectively, is negligible in the means of 20 lines.

The investigation was carried out at $y=13{\cdot}5$ and $y=14{\cdot}5$ independently. The accompanying table gives the result.

TABLE I.—CORRECTIONS TO PROVISIONAL DIVISION ERRORS.

$x=13$.			$x=14$.			$x=15$.		
Referred to Lines.	Correction.		Referred to Lines.	Correction.		Referred to Lines.	Correction.	
	$y=13{\cdot}5$.	$y=14{\cdot}5$		$y=13{\cdot}5$	$y=14{\cdot}5$		$y=13{\cdot}5$.	$y=14{\cdot}5$.
	″	″		″	″		″	″
3, 23	+ ·003	− ·042	4, 24	+ ·087	+ ·029	5, 25	+ ·029	+ ·032
4, 22	+ ·026	·000	5, 23	+ ·063	+ ·004	6, 24	+ ·016	+ ·031
5, 21	− ·004	+ ·018	6, 22	+ ·025	+ ·046	7, 23	− ·008	+ ·002
6, 20	− ·015	− ·014	7, 21	+ ·004	+ ·001	8, 22	− ·031	+ ·015
7, 19	+ ·021	+ ·028	8, 20	− ·011	− ·034	9, 21	− ·048	+ ·008
8, 18	− ·027	− ·045	9, 19	+ ·004	− ·001	10, 20	− ·047	+ ·014
9, 17	− ·009	− ·035	10, 18	+ ·006	+ ·016	11, 19	− ·029	+ ·005
10, 16	− ·020	+ ·010	11, 17	− ·046	− ·029	12, 18	− ·042	− ·005
11, 15	− ·024	− ·018	12, 16	− ·011	− ·005	13, 17	− ·031	+ ·044
12, 14	− ·033	− ·027	13, 15	+ ·016	− ·001	14, 16	− ·025	+ ·003
Means 3 to 23	− ·008	− ·013	4 to 24	+ ·014	+ ·003	5 to 25	− ·022	+ ·015
Means 8 to 18	− ·023	− ·023	9 to 19	− ·006	− ·004	10 to 20	− ·035	+ ·012

The two sets of means given are the additional division errors applicable to Eros when referred to reference and comparison stars respectively on Astrographic photographs.

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It will be noticed that line 15 has a considerable bend (″·04) in passing from $y=13\frac{1}{2}$ to $14\frac{1}{2}$, whereas lines 13 and 14 are sensibly straight.

(2) *Systematic differences between the réseau and photographs.*

Fifteen plates were selected so as to be well representative of the different batches of Eros plates. These were one by one compared with the silver réseau; the corresponding lines on plate and réseau being compared at $y=13{\cdot}5$ and at $y=14{\cdot}5$. All the x lines from 3 to 25 were measured on each plate; a selection from the results is given in Tables II. and III. The errors tabulated are referred to the means of lines 9 to 19 as zero. They are differences between the prints and the silver réseau, and consequently are additional to the errors of the réseau itself. A linear term (corresponding to an apparent difference in scale between the plate and réseau) has been removed from the results for each plate. This is necessary if the plate constants a and e, found with the originally adopted errors, are not to be modified. This correction for scale is given in the last column of the tables for ten réseau intervals as applied to line 4, and with reversed sign to line 24, and proportionately to the other lines, and has been applied in forming the results given. It was determined by comparing the mean of lines 3 to 13 with the mean of lines 15 to 25, giving equal weight to each line, to correspond with the system adopted in forming the plate constants.

TABLE II.—COMPARISON OF PHOTOGRAPHIC PRINTS WITH RÉSEAU AT $y=13{\cdot}5$

Plate No.	3	4	12	13	14	15	16	24	25	Corr. for Scale.
	″	″	″	″	″	″	″	″	″	″
5160	−·13	−·08	−·01	−·01	−·02	−·02	−·03	·00	−·21	+·08
5172	−·11	−·06	−·05	·00	−·02	−·03	−·01	+·01	−·20	+·16
5183	+·14	+·14	−·06	−·10	−·06	−·04	·00	+·26	+·04	+·31
5190	·00	·00	−·05	−·04	−·04	·00	−·03	−·01	−·27	+·02
5204	−·10	−·02	+·02	·00	−·01	−·08	−·06	+·21	−·05	+·11
5218	−·19	−·09	+·02	−·07	−·05	−·05	·00	−·07	−·20	+·16
5230	−·09	−·05	+·02	−·03	−·05	−·07	+·04	+·02	−·11	+·11
5239	−·09	−·01	−·01	−·02	−·02	−·07	+·02	+·09	−·15	+·01
5260	−·03	+·01	+·02	−·05	−·04	+·04	+·03	+·03	−·05	+·03
5283	+·11	+·12	−·05	−·05	−·04	−·07	−·01	+·13	−·01	−·04
5307	−·39	−·08	−·03	−·04	−·06	−·02	−·05	+·01	−·20	+·07
5324	−·72	−·39	+·03	−·02	−·07	−·06	−·13	−·08	−·36	+·27
5336	−·08	−·06	+·06	−·05	−·04	−·05	−·03	+·08	−·08	+·04
5352	−·33	−·18	+·03	−·06	−·08	−·11	−·06	−·01	−·22	+·12
5368	+·42	+·36	−·03	−·06	−·04	·00	+·07	+·27	+·05	−·20

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TABLE III.—COMPARISON OF PHOTOGRAPHIC PRINTS WITH RÉSEAU AT $y = 14{\cdot}5$.

Plate No.	3	4	12	13	14	15	16	24	25	Corr. for Scale.
	″	″	″	″	″	″	″	″	″	″
5160	−·12	−·04	+·09	−·05	−·06	−·02	+·01	−·05	−·21	+·10
5172	−·13	−·09	+·05	−·10	−·07	−·07	+·05	−·07	−·23	+·19
5183	+·08	+·08	−·08	−·06	−·06	−·04	·00	+·20	+·04	+·32
5190	−·02	+·04	+·02	−·09	−·04	+·01	+·03	−·07	−·33	+·06
5204	−·17	−·07	+·10	−·06	−·03	−·04	−·03	+·12	−·06	+·12
5218	−·12	−·12	+·01	−·03	−·08	−·01	−·03	+·04	−·08	+·12
5230	−·12	−·11	+·08	−·11	−·02	−·01	+·06	·00	−·22	+·07
5239	−·07	−·07	−·01	−·06	−·05	−·03	−·04	+·03	−·11	+·01
5260	−·05	+·05	+·03	+·01	−·06	·00	·00	−·04	−·09	+·01
5283	+·06	+·13	+·01	−·12	−·04	−·05	+·02	+·09	+·01	−·06
5307	−·39	−·15	+·02	−·12	−·09	−·04	+·03	−·08	−·25	+·07
5324	−·64	−·43	+·04	−·07	−·04	−·03	−·02	−·07	−·29	+·28
5336	−·17	−·11	+·05	−·04	−·03	−·04	−·01	+·02	−·05	+·08
5352	−·31	−·19	+·02	−·07	−·09	−·07	+·02	−·03	−·20	+·13
5368	+·39	+·38	−·02	−·15	−·06	−·01	+·06	+·23	+·03	−·16

TABLE IV.—COMPARISON OF PHOTOGRAPHS WITH RÉSEAU.

MEAN ERRORS OF 15 PHOTOGRAPHS.

x	y, 13·5	y, 14·5	x	y, 13·5	y, 14·5	Probable Error.
	″	″		″	″	″
3	−·106	−·119	25	−·135	−·136	±·028
4	−·026	−·047	24	+·063	+·021	±·022
5	+·017	−·004	23	+·043	+·017	±·016
6	−·026	+·029	22	+·007	+·003	±·013
7	−·003	+·011	21	−·029	+·030	±·011
8	+·056	+·040	20	−·001	+·007	±·011
9	+·029	+·027	19	+·015	+·016	±·009
10	+·023	+·030	18	+·035	+·008	±·007
11	+·021	+·038	17	+·020	+·011	±·006
12	−·006	+·027	16	−·017	+·010	±·007
13	−·040	−·075	15	−·042	−·030	±·005
14	−·043	−·055	14	−·043	−·055	±·004

The mean differences between the réseau and its prints, derived from the fifteen prints examined, are given in Table IV., together with the probable errors of the values found (deduced from the mean discordances of the fifteen prints for each pair of lines). It will be seen that, far from being accurate reproductions of the réseau, the prints differ from it very considerably. Near the

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centre the prints agree very closely among themselves. The mean discordance of the measured position of a line *on a single print* from the mean print ranges from ±″·016 for line 14 to ±″·04 for lines 9 and 19, and to ±″·13 for the extreme lines 3 and 25, increasing regularly with the distance from the centre. The great variability of the outside lines is mainly due to the method by which the scale correction was found. That the irregularity is not entirely arbitrary can be very well seen by examining the differences between the errors of lines 24 and 25 in Tables II. and III. Whereas the absolute errors vary greatly from print to print, the differences are very accordant.

The correction to the place of Eros derived from Table IV. is very considerable. If it is not applied there will be an apparent spurious parallactic displacement of Eros amounting to about 0″·1 between east and west positions, and an error of at least ″·025 in the final value of the solar parallax, deduced from the Astrographic photographs.

(3) *Examination of the Straightness of the Lines.*

So far, all measurements described have been confined to the strip of the réseau near $y=14$, and the result enables Eros to be accurately referred to stars distributed over this strip. But this strip may in the mean have an error relative to the area covered by the reference and comparison stars. If the ruling machine is not absolutely accurate, a curvature of all the réseau lines may exist. Previous investigation had shown that if such a curvature exists at all it must be very small, but it might not be negligible in the present problem.

The straightness was tested by comparing the lines directly with a spider web mounted parallel to them in the double frame of the micrometer as for the comparisons of the réseau and photographic plate. Sir David Gill has described a somewhat similar comparison with a spider line (*Memoirs R.A.S.*, vol. 51), though in that case the réseau line could not be compared directly with the spider-line, as was practicable with the Greenwich measuring apparatus.

In order to eliminate irregularities due to "knots" in the spider line, measures were repeated with the spider line turned over front to back. A more serious error (which was attributed to the slide which carries the spider-line and réseau not moving perfectly in its own plane) could only be eliminated by turning the réseau through 180° and measuring again.*

Experiments were made both on the prints and the réseau

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* When the réseau is turned through 180° the curvature or other irregularities measured against the spider-line will be reversed in direction; instrumental errors will be unaltered. The instrumental error associated with, say, $y=9$ réseau direct will be associated with $y=19$ réseau reversed, so that the instrumental error will not be eliminated from the individual points, but from the means of pairs of points such as $y=9$ and 19, and from the mean curvature.

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itself. For the réseau the investigation was almost entirely confined to line $x = 14$, since it happened to be impracticable (without modifying the micrometer) to measure any other line both in the direct and reversed position. Four sets of measures were made at different times, and the following table gives the results.

Table V.—Curvature of Réseau Line $x = 14$.

(*Sagitta for* $y = 5$ *to* 23.)

Series.	1	2	3	4
	″	″	″	″
Réseau D Wire D	·000	− ·030	− ·022	− ·046
,, D ,, R	...	− ·034	− ·074	− ·030
,, R ,, D	− ·068	...	+ ·014	+ ·002
,, R ,, R	...	...	+ ·006	+ ·006
Means	− ·034	− ·032	− ·019	− ·017

In this table the "curvature" has been measured by the discordance between the middle of the line (represented by the mean of y = 12, 13, 14, 15, 16) and the line joining the two ends (represented by the means of y = 4, $4\frac{1}{2}$, 5, $5\frac{1}{2}$, 6, and y = 22, $22\frac{1}{2}$ 23, $23\frac{1}{2}$, 24). As the réseau was not reversed in Series No. 2, instrumental error is not eliminated from the corresponding mean.

In examining the *photographed* lines the treatment was somewhat different. The aim of the investigation was to obtain the mean error of the central strip with reference to the areas covered respectively by the reference and comparison stars. Eight plates were selected (from the fifteen previously referred to) and measured according to the following scheme. It must be remembered that lines 1 to 13 could only be measured with the réseau direct, and lines 15 to 27 with the réseau reversed.

Straightness of Lines on Prints, Scheme of Measures.

Plate.	Date. 1900.	Réseau Lines. x.	Prints.	Spider Line.
5172	Oct. 20	4, 6, 8, 10, 12, 14	Direct	Reversed
5190	,, 26	14, 16, 18, 20, 22, 24	Reversed	Direct
5204	,, 28	4, 6, 8, 10, 12, 14	Direct	Direct
5218	Nov. 10	14, 15, 17, 19, 21, 23	Reversed	Reversed
5239	,, 15	14, 16, 18, 20, 22, 24	Reversed	Reversed
5260	,, 22	5, 7, 9, 11, 13, 14	Direct	Reversed
5307	Dec. 15	14, 15, 17, 19, 21, 23	Reversed	Direct
5352	Jan. 8	5, 7, 9, 11, 13, 14	Direct	Direct

Measures were made at y = $9\frac{1}{2}$, $10\frac{1}{2}$, $11\frac{1}{2}$, $12\frac{1}{2}$, $13\frac{1}{2}$, $14\frac{1}{2}$, $15\frac{1}{2}$, $16\frac{1}{2}$, $17\frac{1}{2}$, and $18\frac{1}{2}$, and also at either $4\frac{1}{2}$, $5\frac{1}{2}$, $22\frac{1}{2}$, $23\frac{1}{2}$, or $6\frac{1}{2}$, $7\frac{1}{2}$, $20\frac{1}{2}$, $21\frac{1}{2}$.

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Within the area covered by the comparison stars the irregularities appear to be simply accidental. Table VI. shows the results for this area. The means of the vertical columns are made zero. The smallness of the horizontal means seems to show that within this area there is no appreciable error of the ruling machine. The mean deviation from straightness (including error of measurement and accidental error of the prints examined) is ±″·024.

The mean error of the central strip referred to the square 9 to 19* is found (from Table VI.) to be −″·006 ±″·005, a quantity which is almost negligible even for parallax.

In the larger area occupied by the *reference stars* curvature is sensible. For line 14 it amounts to −″·048 (measured by the sagitta from 5 to 23), which may be compared with the results for the silver réseau given in Table V. The results for the other lines cannot be given separately, since instrumental error was only eliminated from their mean. The mean curvature of all the even lines from $x=4$ to $x=24$ (measured in the same way) is −″·020.

It may legitimately be asked whether, in spite of all precautions, the errors determined in the foregoing investigations and the accuracy claimed for the values found may not be to some extent illusory. Is it quite certain that all instrumental errors have been eliminated? Is it certain that there may not be other sources of division error which have not been considered? Fortunately a discussion of the residuals of the comparison and reference stars supplies an independent check on the results obtained by direct measurement. Before the measurements of the réseau and its prints were made, it was realised that considerable corrections were required in order to reconcile the places of the stars determined with the telescope west and east respectively. The plate centre was the same for all plates taken on any one night (evening and morning); if on the evening photographs the image of a star falls at $x=12$ $y=10$, on the morning photographs (with the réseau reversed) it will fall at $x=16$ $y=18$. It can be shown that the difference in the places of the star determined from the two sets of photographs should be equal to the sum of the residual division errors of these two points of the réseau.

An examination of the places of the stars was made for all nights on which at least two plates were taken with the telescope in each position. There were 14 nights thus available; the number of comparison stars discussed was 73, and of reference stars 146. The comparison stars were referred to the mean of the comparison stars on the plate; accordingly the division errors

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[*] It will be seen that the square 9 to 19 is represented by 110 points evenly distributed over it, each measured on at least two prints.

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TABLE VI.—TEST OF STRAIGHTNESS OF RÉSEAU LINES ON PRINTS.

	Plate Direct.						Plate Reversed.						Mean.
y \ x	9	10	11	12	13	14	14	15	16	17	18	19	
	″	″	″	″	″	″	″	″	″	″	″	″	″
18½	+ ·01	+ ·05	− ·01	·00	+ ·02	+ ·02	·00	− ·01	− ·04	·00	− ·06	− ·02	− ·005
17½	− ·01	+ ·02	+ ·02	− ·02	+ ·01	+ ·01	− ·01	− ·03	− ·03	+ ·03	+ ·02	− ·06	− ·004
16½	− ·01	− ·01	− ·03	− ·02	− ·01	− ·01	− ·01	− ·05	·00	− ·05	+ ·01	− ·04	− ·021
15½	+ ·01	+ ·02	+ ·03	− ·01	− ·01	− ·03	− ·03	·00	+ ·05	+ ·01	+ ·01	− ·01	+ ·008
14½	− ·02	− ·07	− ·03	+ ·02	− ·01	− ·01	− ·02	+ ·01	+ ·01	− ·06	+ ·01	− ·01	− ·015
13½	− ·05	·00	+ ·01	− ·03	− ·01	·00	+ ·01	·00	+ ·04	+ ·04	+ ·02	·00	+ ·003
12½	·00	+ ·01	+ ·02	− ·03	+ ·01	− ·02	+ ·01	+ ·06	+ ·03	+ ·01	− ·01	+ ·02	+ ·012
11½	+ ·03	+ ·02	− ·01	+ ·03	+ ·04	·00	− ·01	·00	− ·02	+ ·02	·00	+ ·06	+ ·016
10½	+ ·03	− ·03	·00	+ ·03	− ·03	+ ·03	+ ·02	+ ·03	− ·03	+ ·02	− ·01	+ ·02	+ ·007
9½	+ ·01	− ·02	·00	+ ·02	·00	+ ·03	+ ·02	− ·01	− ·01	− ·03	·00	+ ·03	+ ·001

The two sets of errors for line 14 are derived from plates measured direct and reversed respectively.

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deduced are referred to the square 9 to 19. The reference stars similarly give division errors referred to the square 4 to 24.

Sums of Pairs of Residual Division Errors.

Comparison Stars (from $y=9$ to $y=19$).

$x=$	9, 19	10, 18	11, 17	12, 16	13, 15	14,14
From stars	+″·04	+″·01	+″·06	″·00	−″·10	−″·09
By direct measurement (Table IV.)	+·04	+·05	+·04	+·01	−·11	−·10

Reference Stars (from $y=4$ to $y=24$).

$x=$	5, 23	7, 21	9, 19	11, 17	13, 15
From stars	+″·08	+″·05	+″·04	−″·04	−″·11
By direct measurement (deduced from Table IV.)	+·03	+·03	+·06	+·04	−·08

In the latter table by the division error about line 5 is meant the mean division error between 4 and 6; similarly for the other lines. The division error has been regarded as independent of y, so that all stars between the given limits of x were used.

Fifteen comparison stars fall in the strip bounded by $y=13$ and 15 $x=9$ and 19. After correcting their residuals for the revised division errors which depend on x (Table IV.), the remaining differences (between their positions determined from plates with réseau direct and reversed) should be equal to twice the error of the strip referred to the whole square. In this way we find from the mean of the fifteen stars the error −″·02 ±″·006, which may be compared with the direct determination (by use of the spider-line) −″·006 ±″·005.

The probable error ±″·006 of the result given above was inferred from the discordances *inter se* of the residuals for the fifteen stars. The mean discordance of these is ±″·05, which represents usually Mean of two plates W. − Mean of two plates E., and the apparent correction W. or E. is half this quantity. It results that the mean error of measurement on a single plate is ±″·05 for a comparison star. The error of measurement for a reference star (over the wider field) is apparently much larger.

Royal Observatory, Greenwich:
1907 *January* 11.